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The Evolution of Science Concentrations: The Case of Newcastle Science City

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Abstract

Within the economic geography literature, there has been research undertaken to gain an understanding of how science concentrations have developed. However, most of the research has been based on the listing of chronological events or is rather descriptive. More recently, attempts have been made to apply an evolutionary economic geography (EEG) framework to understand the development of science concentrations as it enables a better understanding of these developments by providing a view on how processes of change operate over time. In light of this, this article utilizes an EEG framework to analyze one type of science concentration, a science city. The case of Newcastle Science City (NSC) is analyzed from 2004 - 2011. The findings highlight that organizational restructuring and the establishment of new organizations, stimulating new connections between individuals and regional organizations and avoiding early lock-ins, facilitates the development of science concentrations.

Keywords: science cities; evolutionary economic geography; high-tech region; technopoles, science policy

1. Introduction

In the context of the knowledge economy, science concentrations such as science parks, technopoles and science cities have demonstrated their important role in collecting capability and human resources, attracting venture capital and producing innovations (2004). The ultimate goal of these concentrations is to bring about economic and business development to contribute to national economies (OECD 2008b). Within the economic geography literature, there has been research undertaken to gain an understanding of how science concentrations have developed to reach their ultimate goals of economic development. Castells and Hall's (1994) seminal book *Technopoles of the World* is the first comprehensive survey to explain how they develop, what each aims to accomplish and how each manages to pass on the lessons to other regions. The other significant research comes from Anne Saxenian on Silicon Valley and Route 128 (A. L. Saxenian 1994). Others including Adams (2011) have also analyzed the development of Silicon Valley. The issues with the findings from this research is that "regional success stories (e.g. Silicon Valley and Emilia-Romagna) are often so much based on culture-based contingencies" and lack a theoretical framework "that transferring polices from these regions to other places is at best difficult'' (Hospers 2006:10). Ignoring this issue, all over Europe there have been great efforts to construct 'Silicon Somewheres' (Florida 2002) which has been an unsuccessful strategy for the above mentioned reasons.

However, more recently, there have been attempts to utilize the notions of evolutionary economic geography (EEG) to better understand how science concentrations such as science parks have evolved[1] (Garnsey and Heffernan 2007; Quere 2007). It has been suggested that an EEG approach enables a better understanding of these developments as it provides a view on how processes of change operate over time (Boschma and Lambooy 1999; Boschma and Martin 2010; Simmie et al. 2008). Key notions such as path-dependency, agglomeration, and organizational adaptation are employed to analyze the development of these science concentrations. This latter research applying an evolutionary perspective has been more successful in providing a way to learn from 'best-practices' as it does not overemphasize the cultural aspects (Kenney and Patton 2006) or what Hospers (2006) calls 'culture-based

[1] Only recently attempts have also been made to apply an evolutionary framework to the case of Silicon Valley (Kenney and Patton 2006).

contingencies'. Instead of emulating best practices or picking winners as a policy strategy, an evolutionary approach suggests building on regional competencies and acquiring sensitivity to local trajectories (Boschma 2005b).

In this article the evolution of Newcastle Science City (hereafter NSC) - one of six English science cities[2] - is analyzed. Against the above background the article addresses the following broad question from an evolutionary perspective: How do science concentrations evolve over time? To address this question, this article aims to apply an EEG framework to the case study of NSC to help analyze how it has evolved since its designation in 2004 until 2011. Specifically, structural change will be discussed to explain the endogenous manner of local actors to engage in collective action to establish new organizations, re-structure old organizations and avoid early lock-ins of sub-optimal technologies to support the objectives of NSC. There is no research to our knowledge which attempts to gain an understanding of science cities from an evolutionary perspective. Indeed, research on the development of science cities is often approached from a chronological perspective (Anttiroiko 2004; Cabral 2004). This article attempts to fill this gap. In developing an understanding of the evolution of NSC, the article proceeds along the following lines.

In section 2, the theory of evolutionary economic geography will be discussed. Section 3 will introduce the case study methodology undertaken for this research. Section 4 will present the case study of NSC and its evolution from a structural EEG perspective. A discussion will take place in section 5. The article will conclude in Section 6 with an overview of the findings, policy implications that stemmed from the findings, and a discussion of some limitations.

2. Evolutionary economic geography conceptual framework

EEG stems from the early seminal work of Nelson and Winter (1982) and Dosi et al. (1988) on evolutionary economics in trying to understand processes of regional growth and change. Current research by Boschma (2010) brought the two literatures together to create a more

[2] There are six English Science Cities. The initial set of three were designated in 2004 including Manchester, Newcastle and York. Added to the original designation in May 2005 were Nottingham, Bristol and Birmingham (HM Revenue and Customs 2004)

systematic theoretical framework (MacKinnon et al. 2009). According to EEG scholars, what has been lacking from existing theories such as 'the New Economic Geography' (Krugman 1991) and 'Institutional Economic Geography' (Martin 2000) is that neither approach explains how the landscape evolves over time (Boschma and Martin 2010). The EEG approach aims to explicate regional change from the underlying industrial dynamics of firms (e.g. geography of entrepreneurship, innovation and extinction) (Boschma and Frenken 2009) and the rise and fall of technologies, industries, networks and organizations (Frenken 2007)[3]. More recently, the role of regional policy within an EEG framework has also been discussed (Asheim et al. 2011; Boschma 2011). The key propositions of an evolutionary approach are based on concepts such as path dependency, co-evolution and structural change. For the needs of this article, we are interested in evolutionary concepts around characteristics of structural change at the level of organizations and sectors. According to Boschma (2005b) structural change includes three core characteristics: (1) restructuring the organizational framework; (2) stimulating new connections between (new) organizations; and (3) avoiding early lock-ins of sub-optimal technologies (Boschma 2005b; Lambooy and Boschma 2001:264). These three characteristics will be discussed in further detail in the below section.

2.1 Restructuring the organizational framework and the creation of new organizations

The discussion around organizations in the EEG framework is linked to the fact that the long-dynamics of economies in space and time are dependent on organizational arrangements and organizational change (Gertler and Wolfe 2002). Indeed, there has been increasing attention towards how organizations can be included in the explanatory framework of EEG (Boschma and Frenken 2009; Nelson and Winter 2002; Pelikan 2003) as they play a role in the dynamic developments of evolutionary paths (Strambach 2010). According to Boschma (2010), regions build up different organizational environments over time which act as incentive and selection mechanisms. "Institutions affect not only the intensity and nature of relations, and, thus, the degree of interactive learning between agents in a regional context, but also the capacity of regions to upgrade, transform or restructure specific institutions required for the development of new economic activities" (ibid: 1008). What is important is whether organizations are flexible

[33] For a full review on the summary of EEG framework, see Boschma and Frenken (2006:291).

and responsive to change when required as this 'dynamic capability' affects the long-term competitiveness of a region.

New organizations as well as the restructuring of old organizations also helps transform the local environment for the development of new economic activities (Lambooy and Boschma 2001). This is based on one of the two perspectives of organizations discussed in EEG which firstly is that organizations primarily influence innovation in a generic sense and co-evolve with technologies over time and differently so in different regions (Boschma and Frenken 2006:291). New organizations develop as new technologies are established. The processes of this change are not market processes but rather complex processes involving the forming of collective bodies, the decisions of voluntary organizations, government agencies and political action and involve the actions of industry associations, technical societies, universities; etc (Nelson 1995). The other EEG perspective on organizations, which is less relevant for the needs of this article, explains territorial differences primarily based on the differences in the history of firms and industries residing in a territory rather than solely on the organizational framework. Studies using an EEG approach may be interested in the history of a company founder and key employees and how their routines transferred from previous activity affects their survival (Frenken 2007).

When looking to studies of organizational restructuring in the economic geography literature to explain the growth of science concentrations, there are various examples where the concept has been utilized. In the Cambridge high-tech cluster, apart from the endogenous process driven by spin outs and emerging agglomeration benefits, 'organizational adaptation' has been used to explain the development of the high-tech cluster (Garnsey and Heffernan 2007). While originally Cambridge University did not provide active support for technology transfer, over time entrepreneurial academics helped transform the university into a more enterprising institution. The transformation within the research is not explained in detail but what this suggests is the importance of organizational change to help support local actors and the role this has on the development of science concentrations[4]. This also links to Strambach's concept of 'plasticity of

[4] The research also highlights how local government and businesses formed 'the Greater Cambridge Partnership' to extend the role of businesses into the policy arena. Additionally, local actors helped to form 'the Cambridge Network' to improve access to US markets.

institutions' which refers to the "elastic stretch of organizations and organizational arrangements and their interpretative flexibility through actors" (2010:407). According to Strambach (2010), organizations may act as enablers where actors can recombine and convert or reinterpret organizations for their new objectives. Of course, the flexibility of the organization depends upon the type of organization. The evolutionary framework Strambach proposes aims to "endogenize the role of organizations, and makes organizations a more integral part of the explanation of the evolution of the economic landscape" (Boschma and Martin 2010:24). In another example of organizational change in a science concentration, the Sophia-Antipolis science park organizational change took the form of a governance shift from a purely private to a public initiative (Quere 2007). This governance shift helped to transform the Sophia-Antipolis from a 'City of Science' to an 'International Industrial Park' which helped to assure the sustainability of the project. In Silicon Valley, organizations and technological trajectories co-evolved to create an ecosystem for entrepreneurs (Kenney and Patton 2006).

2.2 Stimulating new connections between individuals and regional organizations

While the first feature of structural change from an EEG perspective focused on restructuring the organizational framework, the second feature involves further stimulating connectivity between new or restructured organizations at a regional level (Lambooy and Boschma 2001) or in some cases of peripheral regions instigating the connections in the first place. Lambooy and Boschma (2001:261) argue that policies should "ensure that all organizations that make up the system span all the necessary range of activities (that is, none are missing or underdeveloped) and that these organizations interact intensively". This concept is based on the systems of innovation literature which stresses that innovation is interactive and involves various organizations including universities, research institutes, public sector organizations and firms (Cooke et al. 2000). It is the interaction between the knowledge generation and exploitation of sub-systems which leads to the commercialization of new knowledge (Cooke et al. 2004). Geographical proximity enables these organizations to interact and facilitates the exchange of tacit knowledge (Boschma 2005a). The more intense the interaction between the different parts of the system, the more dynamic the system will be (Carlsson et al. 2002). However, it is not a critical mass of organizations within a regional innovation system which is important but rather its capacity to coordinate the actions of these organizations (Boschma 2004). Cooke (2005:44) further explains this in relation to Silicon

Valley where he argues that Silicon Valley's success was not due to its focus on technology which many people suggest but rather that it was "the first place to systematize the process of interactive innovation". This systematization, Cooke (2005:47) goes on to explain, was Silicon Valley's capability in "crossing boundaries" from knowledge *exploration* (laboratory bench) to knowledge *exploitation* (to the market). Stimulating new connections between organizations is also underpinned by the literature around networks. Saxenian (1990) analyzed local networks in Silicon Valley and concluded that they were essential for exchanging and sharing knowledge between individuals and regional organizations such as universities, trade associations, businesses, and venture capital firms.

The key question is how to coordinate these different organizations which reflect different cultures, have different objectives and respond to different incentive mechanisms (Dasgupta and Stiglitz 1980). Some argue that government may have a role as a "broker" and network facilitator (Lambooy and Boschma 2001). Informal networks amongst members of a common community of practice has also been discussed (Metcalfe 1994). The transformation in the relationship between university, industry and government as key actors within the regional innovation system is also a suggested strategy (Etzkowitz 2003). According to Etzkowitz (2003:308), university, industry and government "enter into a reciprocal relationship with each other (mostly at the regional level) in which each attempts to enhance the performance of the other". The initial level of interaction is usually collaboration taking place through their traditional roles and typically begins via discussions to improve the local economy, develop a regional growth agreement, or establish a technology council. At a latter stage, each partner "takes the role of the other" while at the same time maintaining its primary role and distinct identity. Etzkowitz (2003) uses the example of government to demonstrate this point where government's main responsibility is providing the rules that govern society, it now also makes venture capital available to help start new enterprises.

2.3 Avoiding early lock-ins of sub-optimal technologies

The third feature of structural change within an EEG framework is to reduce the risk of lock-in of sub-optimal technologies in order to keep open a wide range of opportunities for regional

development (Boschma 2005b). The overall goal is to find a balance between focusing on maintaining diversity while at the same time not keeping too many options open at the risk of absorbing excessive amounts of resources. This involves preventing the early exclusion of new trajectories with major growth potentials and links to the importation of path dependent ideas into economic geography as an explanation of science concentrations. However, before discussing how to achieve this, literature around path dependency and its link to lock-in will be discussed since it underpins the above perspective.

An EEG approach suggests that path dependence is "a probabilistic and contingent process (whereby) at each moment in historical time the suite of possible future evolutionary trajectories (paths) of a technology, institution, firm or industry is conditioned by (contingent on) both the past and the current states of the system in question, and some of these possible paths are more likely or probably than others" (Martin and Sunley 2006:402 and 403). More simply put, path dependence is a consequence of history. Over time as certain trajectories become established they may become locked-in as a result of path dependence and can negatively affect innovativeness and renewal. Grabher (1993) demonstrated the role of path dependence and lock-in as explaining the lack of revitalization in old industrial areas. When looking to the perspectives of path dependence which exist in the literature, Martin and Sunley (2006) provided a thorough review which suggests there are four perspectives: path dependence as technological 'lock-in', path dependence as dynamic increasing returns, path dependence as institutional hysteresis and more recently regional path dependence.

Linked to path dependence and important for understanding how new paths come into being in a lock-in situation, is the idea of path creation (Martin and Sunley 2006) . Martin and Sunley (2006:418) contend that in a lock-in situation, regional systems can continue to follow a developmental path that is either downward and negative or, in contrast, upward and positive. Regional systems in a downward and negative path fail to recover from external shocks and decline, while regional systems in an upward and positive path grow stronger from external shocks. This sheds another light on the concept of path dependency and lock-in. Compared to existing path dependency literature, it also addresses the possible negative and downward effects of lock-in, but in addition to that, it adds the possibility for regional systems to overcome lock-in and use the lock-in situation with its existing knowledge, networks and competences, as a

starting point to create a new positive and upward developmental path. In line with this, Simmie et al. (2008) also elaborate on this notion that new paths emerge in the context of existing paths of technology and institutional structures. A path's direction is determined either by a chance event or by purposive behavior by agents. A critical mass of activity around a path then develops which then enables the path to become locked-in. The path usually declines over time, however in some cases it continues and is renewed and extended. The start of new pathways can be attributed to the following reasons: indigenous creation, heterogeneity and diversity, diversification into technological related industries, upgrading of existing industries and transplantation from elsewhere (Martin and Sunley 2006:420).

In the context of path dependency and creation, structural change practices "ensure diversity in order to increase regional adaptability, to keep open a multiplicity of potential resources for new trajectories, and to allow for new, unexpected combinations" (Boschma 2005b:263 and 264). According to Wolfe (2010:151), while there are path dependent processes at work, these processes intersect and may be shaped by the choices of local actors: "Path dependence plays a role in determining outcomes, but the role is contingent; it is framed by the strategic choices of local actors and the degree to which local institutional structures constrain or support the realization of those goals". This can be seen in the case of the Ottawa and Waterloo high-technology clusters. What is important here is that Wolfe suggests that path dependency is not just random or chance events which influence the industrial structure of a region but rather can be influenced by civic capital and governance at a local level. This involves strong civic leadership, the ability to create coalitions and the capacity for undertaking and revisiting focused plans (ibid). Geenhuizen and Nijkamp (2006) support this view and also explain that regional (urban) actors' role in the prevention of path-dependency is through critical reflection and learning on their own performance and institutional arrangements and through continuous innovation.

Based on the above review of the literature, our framework (see table I) will be used to analyze the case study. The first column presents the three core characteristics of structural change (restructuring the organizational framework, stimulating new connections between individuals and regional organizations, and avoiding early lock-ins of sub-optimal technologies), explicitly

discussed in the above sections. The second column further explicates the structural change processes. Restructuring the organizational framework can be seen when organizations are used by local actors to recombine and convert or reinterpret organizations for their new objectives. Stimulating new connections between individuals and regional organizations is a process that involves building partnerships and between individuals and regional organizations. Avoiding early lock-ins of sub-optimal technologies is also a process that prevents the exclusion of new trajectories with major growth potentials. The final column presents examples of other science concentrations and how EEG concepts were used to explain their development.

TABLE I SHOULD GO HERE

3. Research Methods

The research design is based on a case study approach. Scholars utilizing an EEG framework acknowledge the value of utilizing case studies to analyze regional specificities from a dynamic perspective and as a tool in appreciative theorizing (Boschma and Frenken 2006). The research methods stemmed from the methodology of Eisenhardt (1989). The advantages of this research approach include "the potential to generate theory with less researcher bias than theory built from incremental studies" (ibid:546) and "the likelihood that resultant theory will be empirically valid" (ibid:547). The research began by defining the research question: *How do science concentrations evolve over time?* A priori constructs were then taken from the EEG framework such as 'restructuring organizational framework', 'stimulating new connections between organizations' and 'avoiding sub-optimal technologies'.

Multiple data collection methods were chosen involving observational analysis, document analysis and semi-structured interviews with actors in the chosen case study (see table II). A case study approach characteristically joins data collection methods such as archives, interviews, questionnaires and observations and enables triangulation of evidence (Eisenhardt 1989). The observational analysis included attendance at key NSC meetings. The document analysis involved the analysis of significant documents which provides information on NSC's evolution.

Semi-structured interviews were conducted with actors within and working for NSC, each lasting approximately 60-90 minutes. The interviews were recorded and transcribed for analysis purposes. Additionally, informal discussions with several NSC staff members and key North East regional actors were also held. Besides the use of multiple research methods to enable triangulation of findings, which supports the internal validity of the overall case description in this article, the various research methods are used to analyse the development of NSC over time. The case description in section 4 explicitly refers to the representative documents, interviews, observations and discussions.

TABLE II SHOULD GO HERE

The interview data was analysed using codes which stemmed from the research question, conceptual framework and a priori concepts (Miles and Huberman 1984). Other themes analyzed across the interview data included 'roles of actors', 'research themes', 'change' and 'partnership' which complemented the a priori concepts and research questions. From the coded data, explanations were sought in order to address the core research question - How do science concentrations evolve? The findings were then compared with conflicting and similar literature to "build internal validity, raise theoretical levels, and sharpen construct definitions" (Eisenhardt 1989). This process helped to shape hypotheses which were developed. These are presented in the discussion section. The next section will present the case study.

4. Case Study: Newcastle Science City

This section analyzes the case study of NSC. The case is structured by using the three characteristics of the EEG framework and a timeline that consists of three developmental stages. Figure I provides an overview of the timeline of NSC's evolution mapped against the EEG characteristics of structural change discussed above. The timeline is divided into stages (stage I, stage II and stage III) from 2004 to 2011. In the case description in this section, successively, for each EEG characteristic, the crucial decisions and events will be presented from stage I until stage III. The case study starts with an introduction into the background of NSC.

FIGURE I SHOULD GO HERE

4.1 Background

4.1.1 The Science City Concept

A Science City is defined as "new settlements, generally planned and built by governments, and aimed at generating scientific excellence and synergistic research activities…within a high quality urban space" (Castells and Hall 1994:39). Its policy purpose is to encourage a particular type of industrial activity, research and development, in locations where it would otherwise not take place (Appold 2004) as a tool of regional development (Castells and Hall 1994). The concept combines 'science' and an 'urban' setting where the 'urban' dimension refers to location, infrastructure, industrial and other services (Anttiroiko 2004). Science cities have developed over the years and are categorized in the literature into three waves: 1st wave: purpose-built campus-based new towns; 2nd wave: large scale capital developments on the outskirts of existing cities; and 3rd wave: place science-based economic development within existing metropolitan areas (Charles 2010). According to Castells and Hall (1994), there are key issues which shed light on science cities' genesis, structure and outcomes which are: successful synergy in technopoles involves a combination of innovations; in developing technopoles state-private sector relationships are characteristic of the mature capitalist state; the role of universities in helping to develop technopoles is important; venture capital goes increasingly where high-tech industry already is; critical synergistic effects depend on specific forms of social organisation and institutional support; and technopoles need enough time to grow and mature which may take 20 to 30 years.

NSC represents a third wave science city which was designated by the UK national government in 2004. It links most closely with the definition put across by the OECD (2008a:210) as "a delimited spatial area where science, technology and innovation is actively used to promote economic and business development". Unlike first and second wave science cities, NSC is deliberately woven into a pre-existing metropolitan area (Newcastle upon Tyne), uses science

(broadly defined) as a tool for regeneration, has a broader social mandate to deliver social objectives and tends to be more highly networked (Charles 2010:136).[5] It is a bottom-up public-private partnership between three key local actors which will be discussed in detail in a following section. From 2004 to 2011, NSC has contributed to the economy of Newcastle (Newcastle Science City 2014) (see Figure 2 which provides an overview). A recent consultancy report (Bright Purpose 2011) ,which evaluated NSC's economic impact on Newcastle found for example that businesses created with support from NSCL reported forecast turnover increases that could be attributed in part to NSCL, varying between 20% and 40% attribution by 2013.

FIGURE 2 SHOULD GO HERE

4.1.2 Newcastle University

Newcastle University was first established in 1834 as a College of Medicine in Newcastle upon Tyne. Newcastle is the only city in England where university teaching began in the faulty of Medicine so it has a long standing in scientific endeavors. It is part of the Russell Group of Universities and is known as a research intensive University with early roots as a civic university based on regional demands of the industrial economy. This concept of a 'civic university' resurfaced in 2007 with the newly appointed Vice-Chancellor at that time and has become part of its current aims and objectives to "play a leading role in the economic, social and cultural development of the North East of England" (Newcastle University 2012). This aim is strongly linked to the reason for getting involved as a core partner of NSC, which also has the goal to contribute to the economic development of the North East region. To respond to "the demand side of societal challenges" which is outlined as part of its 'civic university' objectives, the University recognized that it needed to make changes. Despite its history as a research intensive University, which suggests that it most likely would not be successful in contributing to NSC and its objectives (Castells and Hall 1994), the University made changes to assume an entrepreneurial role in the initiative. When looking to the organizational changes within

[5] For a further explanation and literature review on types of Science Cities see Anttiroiko (2004).

Newcastle University, they can be grouped into three stages (see Figure 1) which will be discussed in detail below: the emergence of the Business Development Directorate (BDD) (pre-science city designation), organizational changes (post-science city designation) and further BDD restructuring (post-science city designation). Stage 1 of the restructuring has also been included in the case study, despite its occurrence pre-science city designation, as the changes during this period affected Stages 2 and 3.

4.2 Restructuring the organizational framework and the creation of new organizations

The first structural change which explains the evolution of NSC is the restructuring of Newcastle University into an 'entrepreneurial university'.

4.2.1. Stage 1: *Pre-Science City Designation*

The first stage of the structural change pre-science city designation involved the establishment of the BDD in 2003 which set the foundation for the University becoming 'open for business'. Four business development managers (BDM) were appointed within the University at a faculty level based on the key research strengths of the University. This change was fundamental for the start of the commercialization of research as it was the first time that individuals within the University started to approach academics about their business ideas which is highlighted by a BDD Manager:

"So basically they recruited four individuals with commercial backgrounds in the different areas of science. I started walking around talking to people and within about three days, I have a project list like this (raises hands out wide). *I am not kidding it was scary. I was walking into places and they were saying oh, this is great you know we never had anybody come and talk to us about this before could you help me commercialize this"* (BDD Manager Interview, 2011).

Furthermore, the establishment of the BDD brought all business development activities under one umbrella and under one individual who led the unit. Prior to this change, it was recognized within the University that the pre-BDD unit activities were not successful in establishing Newcastle University on the trajectory of becoming an entrepreneurial university. As highlighted by a business development manager who worked at the unit during that time: *"I think it changed. I like to think our team, when we came in we were involved in changing that, and there was recognition that it was suboptimal"* (BDD Manager Interview, 2011).

Fundamental to the decisions around these changes, the Vice Chancellor (VC) was a key actor who had the power to make changes at a high level within the University. The particular VC in charge of making changes was the start of the university's initiative to appoint VCs with experience in commercialization and entrepreneurship. This change had two effects. The first is that the VC made the necessary organizational changes to the University which included the formation of three large faculties and 27 schools to promote integration across the hierarchy. This restructuring made it possible for the University to adopt a more corporate response to opportunities in its external environment and helped the University rediscover its roots of "excellence with a purpose" (Goddard 2008:15). The VC also had an effect on the ability of the university academics to spin-off companies as the VC provided support and encouragement for academics starting businesses. As explained by one academic: "*I think the most helpful person at the early stages was the Vice Chancellor. In fact the Vice Chancellor's which had knowledge of the company I always found them to be very helpful…*(through) *conversations and encouragement*" (Newcastle University Academic Interview, 2011). The VC's support, encouragement and knowledge of the spin-off process stemmed from his past experience of starting his own company which according to a senior staff member of the University "*counts for a lot in dealing with members of academic staff some of who took a lot of convincing that this was the right thing to do*" (Senior Staff Member Newcastle University Interview, 2011).

4.2.2 Stage 2: Post Science City Designation

After the designation of Newcastle as a Science City, the University's commitment towards becoming an 'entrepreneurial university' continued which can be seen in its input towards the original prospectus of development for NSC which describes the transformation from a strictly research oriented organization to one which was "open for business and economic development" (Newcastle Science City 2005). As described by the University: *"By 'open for business and economic development', we mean the implementation of a model by which the University undertakes its activities in the closest contact with business and those concerned with the economic, social and cultural development of the Region"* (Newcastle Science City 2005:10). To achieve this objective, the University started to make organizational changes which included: *"The development of infrastructure, processes, behaviors, and financial and commercial arrangements that will break down the barriers between the University's expertise and business*

and the wider community" (Newcastle Science City 2005:10). The transformation was made in combination with other stages of transformation the University was already going through (stage 1 discussed above) prior to the Science City designation. This involved "*substantial organizational restructuring, new investment in areas of growth, breaking down traditional disciplinary boundaries, and exploring new approaches to business engagement"* (Newcastle Science City 2005:10).

In addition to the University adapting its processes and behaviors, it also developed its scientific research base which was key to Newcastle becoming a science city. Four key research themes (Molecular Engineering, Energy and Environment, Stem Cell Biology and Regenerative Medicine and Ageing and Health) also known as 'societal challenge themes' within the University were identified based on existing regional strengths where there was major potential for growth in both scientific research and economic application. Each research theme was headed up by a 'science city theme leader' or successful Professor in the given area within the University. Since their inception, the key research themes have evolved which will be discussed in further detail in section 4.4. Along with the changes to the University's research base, the University hired four Professors of Practice (PoP) linking to the key research themes and established posts within the Business School. The PoPs were funded by One North East which was one of the core partners of NSC. These individuals all have PhDs and have worked or started businesses themselves in the four research areas which Science City is trying to develop. Their role within the University was "to serve as a role model for faculty members thinking about developing a start-up and, also as a link between the University's Business School and Science and Engineering Departments" (Dzisah and Etzkowitz 2007:171). They were also encouraged to collaborate with the University's newly established 'science city theme leaders' to develop activities and deliver Science City initiatives (ibid). From the University's perspective, the role of PoP correlates directly with its mission of being "at the forefront of understanding business and professional practice and policy…and play a central role in the work being done by School and University for Newcastle Science City" (Newcastle University Business School 2011). According to a POP, the role was more successful in two of the four research areas:

"*Of the four positions, I think two were reasonably successful and were continued…The two that were quite successful, energy and environment and healthy ageing they were already University*

institutes and people working in these areas and the two professors of practices who worked there just slotted into the existing framework" (POP Interview, 2011).

4.2.3 Stage 3: Post Science City Designation

The third stage of the University restructuring (which was being undertaken at the time of writing this article) involved the re-organization of the BDD unit for a second time. The restructuring of the BDD demonstrates that the University still needed to undergo structural changes in order to successfully reach its objectives of becoming an entrepreneurial university. The new BDD unit was renamed to Research Enterprise Services (RES) and the structure changed from a centralization system to a faculty-based system in order to streamline activities. Three business development managers within the BDD unit were appointed to the three faculty levels within the University and act as a first point of contact for academics wanting to establish businesses. Academic leadership will come from the dean and professional/administrative commercial development team. A newly formed 'Venture Unit' was also established to provide more support to academic spin-offs post spin-out stage for the University to help further support the success of their ventures. How this will work on the ground is yet still to be seen.

The second structural change which explains the evolution of NSC can be seen in the establishment of Newcastle Science Company Limited (NSCL) which will be discussed below.

4.2.4 Stage 2 and 3: Newcastle Science Company Limited

In 2009, based on NSC's original prospectus for development, NSCL was incorporated as a special purpose vehicle to take forward the objectives of NSC on behalf of the three core partners. The creation of this new organization represents the partners attempt to establish permanent governance, accountability and delivery structures for NSC. NSCL established governance and a board structure made up of representatives from the core partners as well as developed a team structure including a Chief Executive, Finance Director, Program Director, Office Manager, Quality and Compliance Manager, Project Manager and Finance Manager. Establishing this new organization and appointing a Chief Executive[6] of NSC to provide leadership within the initiative was important to the evolution of NSC as it was through his

[6] In 2011, the Chief Executive of NSC decided to step down to pursue other opportunities.

leadership that the initiative started to produce tangible outcomes to NSC such as science-based start-ups, engagement with schools in the region and the establishment of networks with local actors. This point was highlighted by a senior staff member at Newcastle University: "*When the CEO arrived...he came with all sorts of ideas about how it* (science city) *could work and that was very helpful...where is the money going to come from*" (Senior Staff Member Newcastle University Interview, 2011).

On an organizational level, NSCL established a core vision which the partners worked together across the region to achieve: *"We are here to ensure the creation of prosperity from Science for Newcastle"* (Newcastle Science City 2009). Based on this vision and the original prospectus for development, NSCL established five core strands of activity which included: Science Partnership, the Newcastle Innovation Machine (NIM), Science Enterprise, Science Central and Education, Skills and Community. Overtime, that vision has changed as the partners have been able to further understand how the creation of prosperity from Science for Newcastle can be achieved. The vision has since then been adapted to the following: *"Our mission is to promote scientific excellence, create and support innovative high-growth businesses and engage the local community so that everyone can become part of our city's continued scientific achievement"* (NSC 2011).

To support this further developed vision statement, NSCL also restructured the five core strands of activity and also changed some of the activities' titles. These structural changes were a direct result of the NSC partners and NSCL learning and understanding what it means to be a science city and the types of activities they should be undertaking. As explained by a senior staff member of NSC: *"I believe because the organisation is only about 3 years old as times progressed we have learned and we have put in more systems and processes and we have identified opportunities where we can exchange our support activities and contribute towards what the partners really wanted"* (Senior NSC Team Member Interview, 2012). Most recently (while writing this article), it was announced that in response to financial challenges created by governments cuts to funding and the abolition of One North East, overall costs of the NSC will be reduced. Newcastle City Council and Newcastle University will continue to invest up to £500,000 each year in NSCL for the next three years. However, this reduction will change the

future core activities of NSCL which is still yet to be known. The next section will discuss further structural changes which included stimulating new connections between these new and restructured organizations.

4.3 Stimulating new connections between (new or restructured) organizations

4.3.1 Stage 1: Partnership Formation

The second structural change involves the partnership formed between NSC's 'core partners'. These 'core partners' as they became known are: Newcastle University, One North East (the local regional development agency)[7] and Newcastle City Council. While national funding was expected to follow the designation, no funding was eventually given to Newcastle. As explained by a senior staff member of Newcastle University:

"*The original belief was the government would back Science City with government money and some of that additional source of money would come to the University…Then it was realized after about a good couple of years, look there is never going to be any money. Science City was a flag to fly. You are a Science City but there is not going to have government money flowing with it. I think at that point in time it all changed and people began to think 'well how are we going to get this as a source of money? How much money are we going to have to put in, what is the partnership going to look like. What are the returns to the partners going to be, how are they going to be determined?', and so on"* (Senior Staff Member Newcastle University Interview, 2011).

As a result, the three key local organizations within the North East region established a partnership to take the science city designation forward. This partnership was established shortly after the science city designation and fostered communication between three very separate and different regional organizations stimulating new connections. According to research completed by Manford (2007), there was an inter-organizational pressure where no organization wanted to 'miss out' on the opportunity to participate in ensuring the successful achievement of Science City for Newcastle. The initial communication between the organizations was based around understanding what the designation meant for each organization, and how it could be best exploited for the benefit of the city and region. On an individual organizational level, each organization realized that the Science City designation could be utilized to achieve their separate

[7] One North East closed down in March 2012 as a result of the change in government in the UK.

developmental goals. For the University, it meant to continue achieving scientific research excellence. For the City Council and One North East, NSC would contribute to their regional development objectives.

The lack of funding provided by the government was important as it "forced" these 'core partners' to come together as a 'bottom-up initiative' and establish Newcastle as a science city based on local needs. This has been announced by the government as a policy to leave cities to work objectives out for themselves. This progress that science cities made in regards to bringing various stakeholders in the region together has been recognized by the government: "*DIUS*[8] *recognizes the progress that Science Cities have made in developing partnerships across a range of organizations, public authorities and businesses to achieve shared innovation priorities. The Science City Programme shows how science and innovation partnerships can work well across institutions"* (DIUS 2008:83 and 84). Despite the differences in the organizations and their objectives, all partners agreed to share one third of the responsibility and equally contribute financially to the initiative. For example, in 2005, one year after Newcastle's designation as a science city, the partners purchased what had been the site of the former Newcastle Brewery to develop what is to become 'Science Central', a physical infrastructure for the urban incubation of science-based businesses. The ownership of the land was split in three ways. The partnership also established a Leadership Group led by Paul Walker, Former Chief Executive of SAGE Group Plc to the drive the development of NSC. The Leadership group was also supported by a Task Group led by One North East and with membership drawn from Newcastle University, Newcastle City Council and a wide range of other key stakeholders. A 'core partners meeting' to discuss the activities of NSC takes place on a monthly basis and has attendance by all key local actors involved with the NSC initiative.

4.3.2 Stage 3: Partnership Reformation

More recently, in 2011, the partnership changed dramatically when One North East announced its closure. This announcement drove the two other partners, Newcastle University and

[8] DIUS was the Department for Innovation, Universities and Skills, and has most recently been renamed as BIS or the Department for Business Innovation and Skills.

Newcastle City Council, to consider future organizational changes as well as taking up the responsibilities of the third partner. As explained by the Newcastle University's Vice-Chancellor:

"*Weathering that storm* (the closure of One North East) *will mean that we will make some organizational changes. We will restructure, we will adapt but we remain firmly committed to the vision as it has been set out originally by One North East and by the board of Science City and so on. When One North East goes out of existence at the end of the month the three way partnership will go back to a two way partnership in terms of the land at science central. We have had the approval now from London that we are committed now to buy, the city council and the University are committed to buy One North East's share of that land which we will do*" (Newcastle University Vice-Chancellor Scientia Speech, 2011).

The Newcastle City Council Chief Executive also expressed his commitment to NSC:

"*My mantra certainly as chief executive of Newcastle City Council for the last two years has been let's finish what we've started and this project is something that we will finish over the next decade or longer and that is important to us and we still see this as an investment priority"* (Newcastle City Council Chief Executive Scientia Speech, 2011). The next section will discuss the third category of structural changes which included avoiding early lock-ins of sub-optimal technologies.

4.4 Avoiding early lock-ins

4.4.1 Stage 1: Selection of Key Research Areas

The development of the scientific research base is the 'science' part of the science city and is an important underpinning element for NSC to reach its objectives. It is the research base which is utilized by individuals within science city to create spin-offs into a network of industrial firms and business ventures as well as attracting investment. As mentioned above, the initial four key research themes established in the original prospectus for development included: Molecular Engineering, Energy and Environment, Stem Cell Biology and Regenerative Medicine and Ageing and Health. In selecting the areas of focus, the partners built on a number of key principles:

- Focus on areas of existing strength and where there is major potential for growth;

- Focus on areas which will have broad relevance across a range of industries or applications;
- Focus on disruptive or solution oriented areas;
- Focus where there already is or will rapidly be potential to create a critical mass (Newcastle Science City 2005:13).

Further describing the establishment of NSC's key research themes, a senior NSC team member explained:

"*When they decided to nail this down to three key areas it was pretty much to look at ok, what are the strengths in the region, what is happening, what can we promote the region as, so what are the things that the region has, this is what we are strong in these are our skills, these are our technologies we are trying to develop and when we look at those and when we look at those questions I guess the logical answer to those questions are we are pretty strong in ageing and health, there is enough evidence to show the research that is happening, the money that we are attracting, the region is strong in sustainability there is a lot of evidence to show that there is work happening in offshore wind turbines, big companies are interested in the region to set up a base for the offshore wind sector. There is a lot of work happening on green technologies, solar and stuff like that and at the same time there is work happening and a lot of evidence on the work on stem cell and regenerative medicine*" (Senior NSC Team Member Interview, 2012).

The choice to focus on multiple research areas based on existing strengths was important as the partners recognized that *"the probability of a major success in any single commercialization or narrowly defined trajectory is low"* (Newcastle Science City 2005:13). Therefore, they purposely built in diversity to keep open a wide range of opportunities to avoid early lock-ins. This was mentioned in the original prospectus for development: *"There is an additional need to build flexibility into the ongoing development of the research base, in order to enable the sustainable evolution of the Science City"* (Newcastle Science City 2005:12). This meant that the partners were in agreement that the four chosen themes could change as science city progressed and they learned more about where their core strengths and which area would lead to major success. Two of the key research areas chosen (Ageing and Health and Stem-cell and Regenerative Medicine) already had infrastructure in place to help support their activities while a third theme (Energy and Environment) would also soon have a building and institute to support its activities.

4.4.2 Stage 2: Mapping of key research themes

In 2008, to further understand where their strengths were within the key research areas chosen, NSC held a conference called Scientia[08] to develop a science road map. Stakeholders from industry, the universities and schools came together to map the activities currently being undertaken in Newcastle around each of the key research areas to get a view on how competitive it was on a global scale. The results from this activity were then compared against globally renowned views of science progress from internationally acclaimed road maps and then combined with the findings from the conference. The CEO at the time explained the importance of the conference:

"As well as hearing inspiring speakers, we held really productive workshops to collect data for a detailed catalogue of all the science and innovation in Newcastle and identify what is planned in the future…This conference was a fantastic opportunity for us to all to map out Newcastle's science and see for the first time how innovative and pioneering our scientists are right on our doorstep. What it also achieved was that it helped us to explore how we can build on this great base and encourage everyone to become even more successful through collaboration" (Newcastle University 2008).

4.4.3 Stage 3: Change to Key Research Themes

After moving ahead with the four key research themes, in 2009, led by the University, the partners decided to make changes to the original themes reducing the four themes down to three. The Energy and Environment theme was re-named to Sustainability and the Molecular Engineering theme was then absorbed under it. This decision was based on the University's proposition that the medical elements of Molecular Engineering could be easily promoted through the Stem-cell and Regenerative Medicine Theme and that material technology is well-described under the Sustainability theme (Newcastle University 2009). Linking to this was also the desire to create a narrative of "3 Themes in 3 Places" whereby each theme would link to existing infrastructure within Newcastle. The Ageing and Health theme would link to the Institute of Ageing and Health, the Stem-cell and Regenerative Medicine theme to the International Centre for Life and the newly re-named Sustainability theme would link to the core science city building of Science Central.

There is also evidence that firms within Newcastle were also avoiding lock-ins branching out of existing industries into new but technologically related activities to create new pathways. One such example is that of the subsea industry which has been found to be diversifying from oil and gas to new sectors such as offshore renewables (Andriani and Siedlok 2006; Goddard et al. 2012). Companies such as Soil Machine Dynamics (SMD), which is based in North Tyneside, are utilizing their experience in the field of remotely operated vehicles to apply to various offshore renewable projects. The company has seen its share of its turnover from renewables increase from 10% to 30% in the past four years (The Journal 2012). The next section will discuss the findings from the case study against existing literature.

5. Discussion

Based on applying the above methodology through the lens of an EEG framework, we found that NSC's evolution from 2004 – 2011 is based on structural changes at the regional level. Table III provides a summary of the existing literature, the findings from the analysis of the case study and hypotheses derived from the discussion. These points will be discussed in more detail below.

TABLE III SHOULD GO HERE

When analyzing the case study against the first characteristic from the EEG framework (restructuring the organizational framework and the creation of new organizations), the first finding was that the restructuring of Newcastle University into an entrepreneurial university facilitated the development of NSC. This finding is similar to other studies on science concentrations that also highlight the role of university restructuring to facilitate the development of science concentrations (Anttiroiko 2004 ; Garnsey and Heffernan 2007). However, in this study, the way the university was restructured is different. This will be further discussed. In the Anttiroiko (2004) study, it was demonstrated how the IT University in KISTA Science City was restructured to strengthen the area's knowledge-base. The IT University's perspective on

research was widened to new fields and to selected aspects of basic research. The university itself was increased in size to accommodate three times as many students and academic entrepreneurship along with the interaction between the university and IT firms was encouraged. In this study, Newcastle University's restructuring was less concerned with increasing in size but rather focused on joining up business development activities under one unit, promoting integration across the university, establishing core research areas under organised themes, hiring VCs with commercial experience and streamlining business development activities to further support academic spin-offs. In another study, Garnsey and Heffernan (2007) found that the university in the Cambridge high-tech cluster was restructured into an enterprising organization through the role of actors such as entrepreneurial academics and IT experts. Dissimilarly, this study found that the Newcastle University's restructuring was a result of senior actors within the University such as the VC rather than academics or IT experts, which represents a top-down restructuring rather than a bottom-up restructuring. Dissimilar to other science concentrations (e.g. Kista and Silicon Valley), other key actors within the University also played an important role in NSC's development including Professors of Practice and Academic Science City Theme leaders. The former served as role models for faculty members thinking about developing a start-up, a link between the business school and Science and Engineering Departments and as collaborators with the Academic Science City Theme leaders. The latter provided leadership around key research areas within the University (see Figure 3 for a comparison of the key actors in NSC with Kista Science City and Silicon Valley). This first finding is important as it confirms what others also found which is that university restructuring facilitates science concentration development. It also suggests that universities are heterogeneous in their restructuring activities to become entrepreneurial.

FIGURE 3 SHOULD GO HERE

The second finding was that the creation of NSCL, a new special purpose vehicle (SPV) organization, facilitated the development of NSC. Key regional organizations worked together to establish the SPV to achieve the objectives of NSC. This finding is similar to Anttiroiko's (2004) study who also found that Kista Science City Ltd - a newly formed organization - was

also essential in KISTA's development. Kista Science City Ltd. played a managerial and marketing function and a support system for technology start-ups. In this study, NSCL did not only play a managerial and marketing role as well as support for technology start-ups, it also developed delivery structures for NSC to produce tangible outcomes such as engagement with schools in the region and the establishment of networks with local actors. This second finding is important as it also confirms what others found and links with what Strambach (2010) calls *institutional plasticity* which is that communities of actors are able to recombine and convert or reinterpret institutions into various hybrid forms to serve new or modified goals or objectives. However, the finding also highlights that new organizations can also have an essential role in achieving the objectives of science concentrations. Based on the above, the first hypothesis stemming from the research findings is:

Hypothesis 1: *Organizational restructuring and the establishment of new organizations facilitates the development of science concentrations.*

When analyzing the case study against the second characteristic from the EEG framework discussed (stimulating new connections between individuals and regional organizations), this study found that a bottom-up partnership formed between three regional organizations (Newcastle University, One North East and the RDA) contributed to the development of NSC. The partners worked together, shared one third of the responsibility and contributed financially to NSC. They developed the initial NSC prospectus on what NSC was to achieve, established a leadership group and purchased land to develop the main infrastructure of NSC. Two of the three partners also supported each other when the third partner withdrew from the partnership as a result of being shut down by governmental changes. This finding correlates with the study by Anttiroiko (2004) who also found that KISTA Science City developed as a result of co-operation and 'negotiated order' between the City of Stockholm, big IT firms, real-estate companies and educational organizations. However, unlike the Anttiroiko (2004) study, this study explains in detail how the partners came together and how the partnership evolved. It can also be said that the NSC partnership facilitated the development of NSC by strengthening its nonexistent RIS. This correlates with a study by Coenen (2007), who found that through various public-private initiatives, *specifically* NSC, the North East has strengthened its previously nonexistent RIS.

This is an important finding as has been highlighted that old industrial regions will have weak RIS or "deficits with respect to organisations and institutions and a lack of relations within and between the subsystems" (Tödtling and Trippl 2005:1206). However, in this case of an industrial region, it has been demonstrated that the North East region can overcome such limitations. In this study, the connections were formed between very different organizations with dissimilar objectives which are deemed highly unlikely in the literature by industrial regions. This leads to the following hypothesis:

Hypothesis 2: *Stimulating new connections between individuals and regional organizations facilitates the development of science concentrations.*

When analyzing the third characteristic from the EEG framework discussed, this study found that avoiding early lock-ins of industrial trajectories was a process undertaken by local actors within the North East region. Regional actors in NSC were able to avoid lock-ins through building in a number of key principles to NSC's original prospectus for development (highlighting the importance of flexibility and change in the ongoing development of the research base) and by holding a conference to develop science road maps to understand key strengths. These actors included Newcastle University, One North East and Newcastle City Council as well as local businesses and individuals who attended the Scientia Conference discussed in the case study section. This step was undertaken to enable the sustainable evolution of NSC and to "ensure diversity in order to increase regional adaptability, to keep open a multiplicity of potential resources for new trajectories, and to allow for new, unexpected combinations" (Boschma 2005b:263 and 264). The findings from this study correlate with other research on science concentrations. Anttiroiko's (2004:30) study of KISTA Science City highlights the importance of building 'evolutionary power' and institutional capacity in the Kista area. However, unlike this study, he does not explain in detail how this is achieved. This study also correlates with the findings from a study on the Ottawa and Waterloo high-technology clusters which also found that local actors played a role in achieving regional agendas (Wolfe 2010). This third finding is interesting as it can contribute to the discussion surrounding bringing a theory of agency into EEG as although path dependence focuses on a sequence of specific micro level events, it does not have an explicated theory of agency (Martin and Sunley 2006). Our research highlights that

science concentration evolution should be understood as “an ongoing never ending interplay of…path creation and path destruction that occurs as actors in different arenas reproduce, mindfully deviate from and transform existing socio-economic technological structures, socio-economic practices and development paths” (ibid: 408). Based on the findings from this study, the following hypothesis is:

Hypothesis 3: *Avoiding early lock-ins facilitates the development of science concentrations.*

The next section will summarize and discuss some final conclusions.

6. Conclusion

The central aim of this article has been to contribute to understandings of how science concentrations evolve over time. By utilizing an EEG framework as a conceptual lens it has been shown that organizational restructuring and the establishment of new organizations, stimulating new connections between individuals and regional organizations and avoiding early lock-ins is related to the development of science concentrations. The first structural change involved a newly formed partnership between three dissimilar organizations (Newcastle University, Newcastle City Council and One North East) which helped to stimulate new connections between existing organizations. The second structural change included the establishment of NSCL as a special purpose vehicle to take forward the objectives of NSC on behalf of the three partners. This organization is what brought tangible outcomes to the Science City designation including spin-off companies, engagement with the local science community and the brand behind NSC. The third structural change was the restructuring of Newcastle University from a traditional research university to an entrepreneurial university including investment in areas of growth, breaking down traditional disciplinary boundaries, and exploring new approaches to business engagement. The last structural change found involved the evolution of the scientific research base from four core research themes (Molecular Engineering, Energy and Environment, Stem Cell Biology and Regenerative Medicine and Ageing and Health) to three research themes (Sustainability, Regenerative Medicine and Ageing and Health). The findings contribute to evolutionary concepts around characteristics of structural change at the level of organizations and sectors in a region and can contribute to the discussion surrounding bringing a theory of agency into EEG.

Based on the study's findings, some policy implications can be discussed. As it was found that science concentrations evolve around structural changes at the level of organizations and sectors in a region, policies may be oriented to transforming the local environment (Boschma 2005b). Rather than just designating specific regions with 'a flag to fly', policymakers should provide guidance to designated regions on how to move forward and develop the designations into tangible outcomes for the region. Following Boschma's suggestions, our study indicates that policies on structural change should focus on: (1) The creation of new organizations and the restructuring of old ones to support the development of science concentrations. (2) Policies should also encourage establishing connections between the newly restructured and created organizations. This can involve bottom-up partnerships between organizations with similar objectives and organizations that have sufficient funding to move forward with their objectives. (3) Policies should focus on avoiding early lock-ins of industrial trajectories. Boschma (2005b) suggests that policies keep open a wide range of opportunities for regional development. Based on our findings we conclude that this may be achieved by building in diversity and flexibility to the original plans for science concentrations so they may evolve over time. Additionally, it may also be achieved by regional policies that encourage regional stakeholders and organizations to come together (at an early stage of the science concentration's development) at conferences to map out their key regional strengths against global research areas.

While an EEG framework is helpful for the needs of this article, it does have limitations. The theory itself is still at an early stage of development whereby some of the fundamental concepts need more elaboration theoretically and empirically. Further research is required to verify the findings reported here. Nevertheless, a number of findings worth further exploration have been identified. An avenue for future research could be to continue to track the changes of a specific science concentration over time to analyze the evolution at a later stage of its development and to evaluate the roles and decisions of actors as well as the economic development impacts on its respective economy.

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EEG characteristics of structural change	**Operationalized change processes**	**Examples**
Restructuring the organizational framework and the creation of new organizations	Organizations are used by local actors to recombine and convert or reinterpret organizations for their new objectives.	Cambridge high-tech cluster – 'organizational adaptation' used to explain development of high-tech cluster (Garnsey and Heffernan, 2007) Sophia Antipolis Science Park – organizational change in the form of a governance shift from private to public initiative responsible for its continued sustainability (Quere, 2007) Silicon Valley – Technology and institutions coevolved to create an ecosystem for entrepreneurs (Kenney and Patton, 2006)
Stimulating new connections between individuals and regional organizations	Stimulating new connections is also essential for building partnerships and exchanging and sharing knowledge between individuals and regional organizations.	Silicon Valley – systematized the process of interactive innovation through crossing boundaries between knowledge exploration and knowledge exploitation; local networks also essential for exchanging and sharing knowledge between individuals and regional organizations (Cooke, 2005)
Avoiding early lock-ins of sub-optimal technologies	Avoiding early lock-ins prevents the exclusion of new trajectories with	Ottawa and Waterloo high-technology clusters (Wolfe, 2010)[a]

[a] While this example does not specifically highlight avoiding early lock-ins, it exemplifies the importance of the deliberate choices of local actors to undertake and revisit strategic plans to influence how pathways to future economic growth and development are shaped.

	major growth potentials.	

Table I: Conceptual framework

Research Methods	Data Sources
Observational analysis	30 NSC Team Meetings 10 NSC Regional Events 1 NSC Core Partner Meetings 1 NSC Communications Group Meeting 2 NSC Away Days 3 Six Science Cities Meetings
Document Analysis	NSC Prospectus for Development NSC Team Meeting Notes NSC Activity Reports NSC Vision Document Pre-Budget Report Leading the Way: Regional Economic Strategy OECD Reviews of Regional Innovation North of England, UK OECD Territorial Reviews Newcastle in the North East Innovation Nation NESTA Report Innovation and the City Realizing the Potential of the North East's Research Base Scientia[08] Bright Purpose NSC Evaluation Newcastle in 2021
Semi-structured interviews	2 Professors of Practice 3 Newcastle University senior staff members 2 Newcastle University Business Development Managers 15 Newcastle University Academics 2 NSC senior staff member
Informal discussions	4 NSC senior staff members 1 CELS[9] senior staff member 1 IPPR[10] researcher

[9] CELS is The Centre of Excellence for Life Sciences is a North East organization that provides comprehensive support to healthcare and life science companies and also plays a key role in the commercial development of research discoveries, bringing professionals and organizations together to share knowledge and collaborate on commercial opportunities (Invest North East England, 2012).

	2 One North East senior staff members 1 NESCI[11] staff member

Table II: Research method and data sources

[10] IPPR is the Institute For Public Policy Research in a UK think-tank organization focused around regional economics, localism and community policy (IPPR, 2012).

[11] NESCI is the North East England Stem Cell Institute is a partnership between various North East Universities and organisations and focuses on the development of new stem cell treatments and providing research tools for drug discovery (NESCI, 2012).

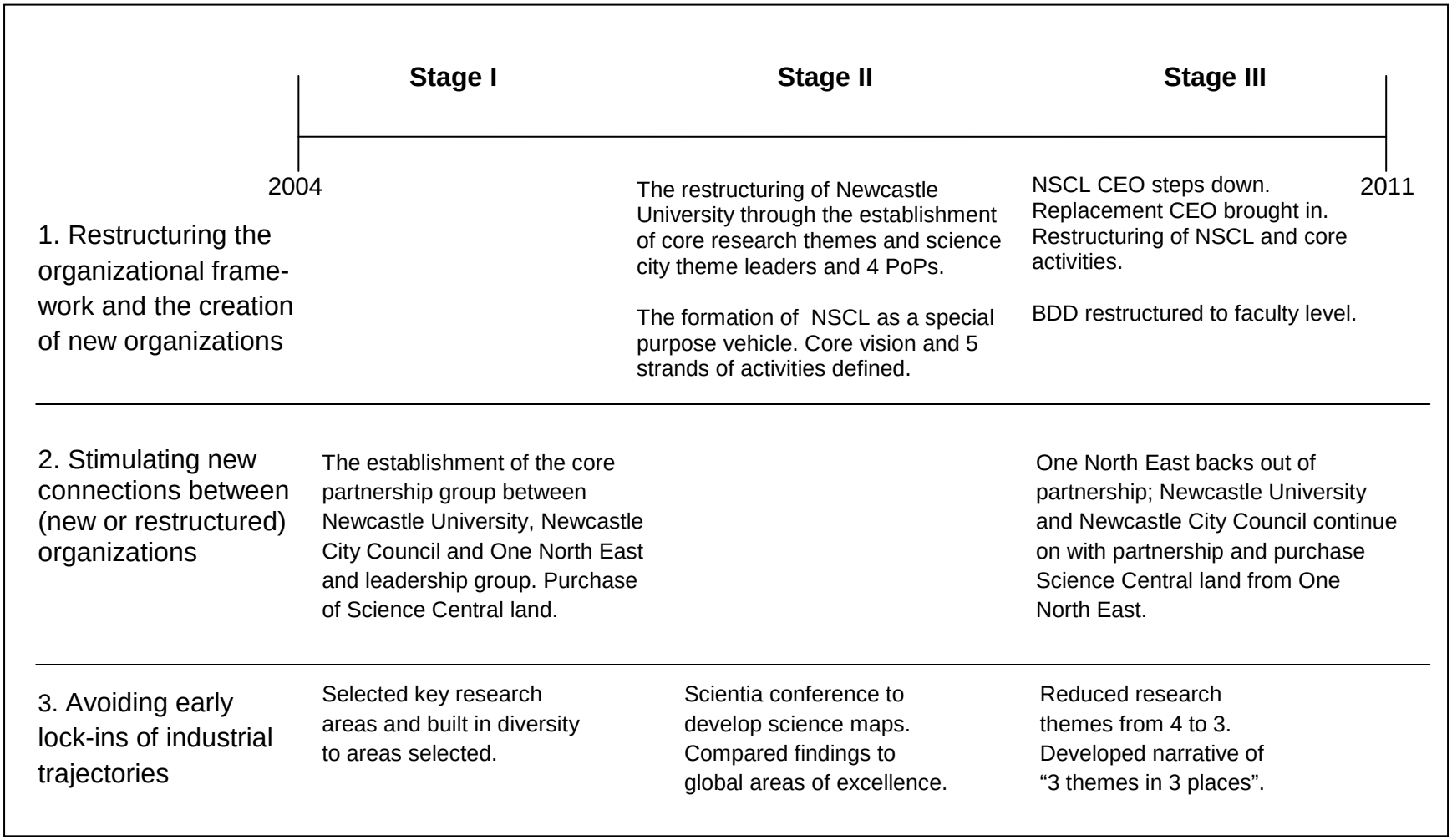

Figure I: Timeline of NSC's evolution mapped against EEG characteristics of structural change

- Supported 755 regional businesses to commercialise new insight-led ideas
- Established 43 companies
- Established 67 jobs
- Reached 5,769 Newcastle residents with NSC's community engagement programme of events
- Reached over 6,000 schoolchildren across the city

Figure 2: Newcastle Science City Outputs (Newcastle Science City 2014)

EEG Characteristics	Existing Literature	NSC Findings	Hypotheses
1. Restructuring the organizational framework and the creation of new organizations	University restructuring in science concentrations: - Cambridge high-tech cluster – bottom-up university restructuring in a science concentration occurs through the role of entrepreneurial academics and IT experts (Garnsey and Heffernan, 2007) - Kista Science City – university restructured in a science concentration including an increase in size to accommodate three times as many students and academic entrepreneurship along with the interaction between the university and IT firms was encouraged (Anttiroiko, 2005). - Silicon Valley - Organizations co-evolved with technological trajectories to create an ecosystem for entrepreneurs (Kenney and Patton, 2006) The creation of new organizations in science concentrations: - New organizations are created to play a managerial and marketing role and a support system for technology start-ups in the development of science concentrations (Anttiroiko, 2005).	University restructuring in NSC : - Top down university restructuring focused on joining up business development activities, promoting integration across the university, establishing core research areas under organized themes, hiring VCs with commercial experience and streamlining business development activities to further support academic spin-offs The creation of new organizations in NSC: - New organization played a managerial and marketing role as well as support technology start-ups. It also developed delivery structures for NSC to produce tangible outcomes such	Organizational restructuring and the establishment of new organizations facilitates the development of science concentrations.

		as engagement with schools in the region and the establishment of networks with local actors.	
2. Stimulating new connections between (new or restructured) organizations	Stimulating new connections between restructured organizations in science concentrations: - KISTA Science City -developed as a result of co-operation and 'negotiated order' between the City of Stockholm, big IT firms, real-estate companies and educational organizations (Anttiroiko, 2005).	Stimulating new connections between restructured organizations in NSC: - Bottom-up partnership formed between Newcastle University, One North East and Newcastle City Council	Stimulating new connections between individuals and regional organizations facilitates the development of science concentrations.
3. Avoiding early lock-ins of industrial trajectories	Avoiding early lock-ins of industrial trajectories in science concentrations: - KISTA Science City highlights the importance of building 'evolutionary power' and institutional capacity in the Kista area (Anttiroiko, 2005) - Ottawa and Waterloo high-technology clusters – importance of deliberate choices of local actors to undertake and revisit long term plans to influence how pathways to future economic growth and development are shaped. (Wolfe, 2010)	Avoiding early lock-ins of industrial trajectories in NSC: - Continuous process undertaken by local actors within the North East region to influence how pathways of economic growth and development are shaped.	Avoiding early lock-ins facilitates the development of science concentrations.

Table III: Summary of existing literature, NSC findings and hypotheses

Newcastle Science City	Kista Science City	Silicon Valley
University (e.g. Newcastle University) • Cooperated with city council, RDA and NSCL • Strengthened area's knowledge-base • Governing body • Purchased land • Provided financial resources **VCs with entrepreneurial experience** • Encouraged academics to start businesses **Professors of Practice** • Served as role models for faculty members thinking about developing a start-up • Link between the University's Business School and Science and Engineering Departments • Collaborated with appointed Academic Science City theme leader	**University (e.g. Royal Institute of Technology)** • Cooperated with large IT firms and city council (Anttiroiko 2004) • Strengthened the area's knowledge-base (Anttiroiko 2004) • Changed the social, cultural, business and scientific environment of Kista (Cabral 2004) **Large IT firms (e.g. Ericsson)** • Provided 40% employment in the IT field in the area • Influenced other IT firms to come to Kista • Played a role in developing area including local university (Anttiroiko 2004) **Real-estate companies** • Managed real estate in Kista • Role in the implementation of Kista's vision (Anttiroiko 2004)	**University (e.g. Stanford)** • Encouraged commercially orientated research (Saxenian 1994) • Promoted the formation of new technology enterprises (Saxenian 1994) • Provided forums for cooperation with local industry (Saxenian 1994) • Promoted collaborative relationships among small firms (Saxenian 1994) • Financial resources to entrepreneurs (Saxenian, 1994; Kenny and Patton 2006) **Dean of Engineering** • Encouraged academic entrepreneurship and supported regional entrepreneurs (Saxenian 1994; Kenney and Patton 2006) **U.S. Military** • Financial resources for entrepreneurs (Saxenian 1994)

Academic Science City Theme Leaders • Provided leadership around key research areas within the University **City Council** • Purchased land • Provided funding • Governing body **Newly formed organizations (e.g.** NSCL) • Marketed area • Operationalised outputs of initiative • Supported start-ups	**City Council** • Purchased land • Governing body • Provide funding (Anttiroiko 2004) **Financial commissioner of the City of Stockholm** • Cooperated with large IT firms and educational organizations (Anttiroiko 2004) **Newly formed organizations** (e.g. Electrum Foundation, Kista Innovation and Growth and Kista Science City Ltd.) • Marketed area • Encouraged key actors to participate in the work of creating a vision for Kista • Supported system for technology startups	**Venture capitalists** • Financial resources for entrepreneurs (Saxenian 1994; Kenney and Patton 2006)

• Ensured cooperation between key actors in NSC • Boosting and developing the networks both in and around Newcastle	• Ensured co-operation between local government and private players • Boosting and developing the networks both in and around Kista (Anttiroiko 2004)	

Table 4: Role of actors in science concentrations